THE APPLICATION OF AIRCRAFT RECONNAISSANCE DATA TO THE ANALYSIS OF THE STRUCTURE OF TROPICAL CYCLONES OF THE EASTERN NORTH PACIFIC OCEAN

Robert LeRoy Pou

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THESIS

THE APPLICATION OF AIRCRAFT RECONNAISSANCE DATA TO THE ANALYSIS OF THE STRUCTURE OF TROPICAL CYCLONES OF THE EASTERN NORTH PACIFIC OCEAN

by

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March 1973

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The Application of Aircraft Reconnaissance Data to the Analysis of the Structure of Tropical Cyclones of the Eastern North Pacific Ocean

by

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Lieutenant, United States Navy
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ABSTRACT

A computer routine composed of two programs was developed to process and analyze aircraft reconnaissance reports for the purpose of diagnosing the structure of the tropical cyclones of the eastern North Pacific Ocean (EASTROPAC). The reports processed by the routine are the Reconnaissance, Detailed Vortex/Center, and the Dropsonde Reports.

Data from the year 1971 were used as a prototype set for the development of the computer routine. The reconnaissance observations were decoded by the first program and analyses were drawn by the second program at various levels between 1000-mb and 200-mb during the storm and hurricane stages of the tropical cyclones. The data proved to be adequate for the purpose of proving the workability of the computer routine, but insufficient for anything but a preliminary analysis of EASTROPAC cyclone structure.

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I. BACKGROUND AND OBJECTIVES

Since the launching of the first operational weather satellite in 1964, interest in the cyclones of the eastern tropical North Pacific Ocean (EASTROPAC) has been on the increase. Prior to that time, a tropical vortex was usually well developed before its existence was even suspected, and almost all information pertaining to these cyclones was obtained from ships which had inadvertently wandered into their paths. The data were, at best, sparse and unprofessionally observed, being useful mainly for the positioning of the cyclone.

With the advent of timely satellite information, cyclones could be detected in the early stages of development, and military reconnaissance flights could be initiated to provide not only confirmation of position, but also real-time measurement of the meteorological parameters in the vicinity of the cyclone. To the knowledge of this researcher, use of these data have not been made for purposes of EASTROPAC research, and, in fact, no comprehensive study of the structure of EASTROPAC cyclones has been undertaken to date.

Simpson and Frank (1970) suggested that the EASTROPAC area be treated merely as an extension of the North Atlantic/Carribbean area, which implies a similarity of the structure of EASTROPAC cyclones with those of the Atlantic; however, Hansen (1972) has shown through climatology that there are significant differences in size, frequency, and behavior between EASTROPAC cyclones and those of the Atlantic, as well as the western Pacific Ocean areas.

Serra (1971) states that inadequate data exist at present for the study of these cyclones and suggests that, as an interim measure, the knowledge of the hurricanes of the Atlantic area be applied to studies of the EASTROPAC cyclones.

This researcher feels that the information collected by military reconnaissance flights since 1964 (perhaps in combination with ship and satellite data) should provide an initial, if not adequate, data base for research into the structure of the EASTROPAC cyclones without undue reliance on cyclone models developed for other ocean areas. The processing and presentation of the appropriate aircraft reconnaissance data for the aforementioned purpose is the major objective of this study.

II. THE NATURE OF THE PROBLEM

For the purpose of this study, the term "structure", as applied to EASTROPAC cyclones, will be limited to the horizontal and vertical distribution of wind, dry-bulb and dew-point temperatures, and the deviation of the isobaric heights from the United States Standard Atmosphere values. These particular parameters were chosen because of their availability and their relationship to the important dynamic and thermodynamic processes of the tropical cyclone. Some or all of these parameters are included in each of the three major types of meteorological reports submitted by military aircraft on cyclone reconnaissance missions, namely the Reconnaissance Report (RECCO), the Detailed Vortex/Center Report (DETAILED EYE), and the Dropsonde Report (DROPSONDE).

The data from the reports just enumerated are available in a coded format from the meteorological worksheets carried by the aircraft on reconnaissance missions. These data exist for varying altitudes (flight levels) and for all stages of development. Before these raw data can be used, they must be decoded and reduced to a homogeneous form. Then they must be properly assembled and analyses drawn before any determination can be made of the structure of the EASTROPAC cyclones. In view of the large variation of the data in both time and space, the manner in which they are to be assembled in order to give the most meaningful result becomes a major consideration. The most straightforward approach might be to assemble all available data taken at (or near) a given level into a

single composite cyclone, or, depending on data density, the same data might be assembled into a composite cyclone at each of the stages of development. The list could go on and on, and each possibility has its own particular merits.

Because of the sheer volume of data available and the multiplicity of ways in which it could be assembled, the approach which best facilitates handling the data, and hence relates to obtaining the most meaningful results, is through the use of the digital computer. (The advantages of using a modern high speed computer for handling large quantities of data in a diverse manner are well known and will not be discussed here.)

III. THE COMPUTER ROUTINE

While a single program might be written which would satisfy the objectives of this study, that program would require vast amounts of core storage and central processing unit (CPU) time for each run. Considerable savings in CPU time could be gained if the job were divided so that the data were decoded only once rather than each time a different investigation is made. For these reasons it was determined that, in terms of overall efficiency, a computer routine made up of two separate programs (hereinafter called PROGRAM ONE and PROGRAM TWO) would best satisfy the objectives of this study.

A. PROGRAM ONE

PROGRAM ONE consists of a main program and six subroutines. It performs three major functions: i) the decoding of the RECCO, DETAILED EYE, and DROPSONDE reports, ii) the transformation of geographic coordinates into moving natural coordinates, and iii) the punching of data cards for PROGRAM TWO. It takes as input punched cards produced from the aircraft reconnaissance worksheets and produces as output both printed tables and punched cards.

The program first reads the six-hourly cyclone center (BEST TRACK) positions obtained from the applicable Fleet Weather Central Guam, Annual Typhoon Report and the associated maximum sustained wind speeds taken from the official forecast bulletins issued by the cognizant Fleet

Weather Central.* This information is then used to compute the course and speed of the cyclone for each six-hour segment of the track, along with the rate of increase or decrease of the maximum wind speed for each six-hour interval. This information is printed in the form of a table, (see Table I) and is stored for use in the transformation of coordinates (see below).

The three types of coded reports are then read, and the RECCO Report decoded in accordance with procedures found on the RECCO worksheet, the DETAILED EYE Report decoded in accordance with procedures found in the "National Hurricane Operations Plan" [6], and the DROPSONDE Report decoded in accordance with procedures found in the United States Air Force Ninth Weather Reconnaissance Wing Manual 105-1, Vol. I [5]. Realizing that future research might utilize other data sources, (satellite, ship reports, etc.) the program was written with enough flexibility so that up to 95 additional types of reports could be processed by making only minor changes to the program. During the decoding process gross-error and missing-data checks are made and such data identified to the program.

The effect of the geographical position of the cyclone system is then removed through a transformation of coordinates. The geographic coordinates (latitude and longitude) of each report are transformed into a

---

* Fleet Weather Central (now Fleet Weather Facility), Alameda, California for EASTROPAC cyclones east of 140W; Fleet Weather Central, Pearl Harbor, Hawaii, for EASTROPAC cyclones west of 140W.

			CYCLONE NAME : OLIVIA			PAGE 1 OF	
			SEP 1971				
2100007	12.40N	88.40W			MAX WIND= 50.0 KTS		BEST TRACK DATA
			COURSE:281.	SPEED: 5.0 KNOTS		ACC= 0.0 KTS/HR	
2106007	12.50N	88.50W			MAX WIND= 50.0 KTS		BEST TRACK DATA
			COURSE:292.	SPEED: 5.3 KNOTS		ACC= 0.0 KTS/HR	
2112007	12.70N	89.40W			MAX WIND= 50.0 KTS		BEST TRACK DATA
			COURSE:292.	SPEED: 5.3 KNOTS		ACC= 0.0 KTS/HR	
2118007	12.90N	89.90W			MAX WIND= 50.0 KTS		BEST TRACK DATA
			COURSE:281.	SPEED: 5.9 KNOTS		ACC= 3.3 KTS/HR	
2200007	13.10N	90.90W			MAX WIND= 70.0 KTS		BEST TRACK DATA
			COURSE:270.	SPEED:10.7 KNOTS		ACC= 0.0 KTS/HR	
2206007	13.10N	92.00W			MAX WIND= 70.0 KTS		BEST TRACK DATA
			COURSE:270.	SPEED:10.7 KNOTS		ACC= 0.0 KTS/HR	
2212007	13.10N	93.10W			MAX WIND= 70.0 KTS		BEST TRACK DATA
			COURSE:275.	SPEED:10.8 KNOTS		ACC= 0.0 KTS/HR	
2218007	13.20N	94.20W			MAX WIND= 70.0 KTS		BEST TRACK DATA
			COURSE:280.	SPEED:10.9 KNOTS		ACC= 0.0 KTS/HR	
2300007	13.40N	95.30W			MAX WIND= 70.0 KTS		BEST TRACK DATA
			COURSE:276.	SPEED: 8.8 KNOTS		ACC= 0.0 KTS/HR	
2306007	13.50N	96.20W			MAX WIND= 70.0 KTS		BEST TRACK DATA
			COURSE:270.	SPEED: 8.9 KNOTS		ACC= 1.7 KTS/HR	
2312007	13.50N	97.10W			MAX WIND= 80.0 KTS		BEST TRACK DATA
			COURSE:270.	SPEED: 8.8 KNOTS		ACC= 0.0 KTS/HR	
2318007	13.50N	98.00W			MAX WIND= 80.0 KTS		BEST TRACK DATA
			COURSE:283.	SPEED: 9.0 KNOTS		ACC= 0.0 KTS/HR	
2400007	13.70N	98.90W			MAX WIND= 80.0 KTS		BEST TRACK DATA
			COURSE:287.	SPEED:13.2 KNOTS		ACC= 0.0 KTS/HR	
2406007	14.10N	100.20W			MAX WIND= 80.0 KTS		BEST TRACK DATA
			COURSE:287.	SPEED:13.2 KNOTS		ACC= 0.0 KTS/HR	
2412007	14.50N	101.50W			MAX WIND= 80.0 KTS		BEST TRACK DATA
			COURSE:287.	SPEED:13.2 KNOTS		ACC= -0.8 KTS/HR	
2418007	14.90N	102.80W			MAX WIND= 75.0 KTS		BEST TRACK DATA
			COURSE:276.	SPEED:13.7 KNOTS		ACC= 0.8 KTS/HR	
2500007	15.10N	104.20W			MAX WIND= 80.0 KTS		BEST TRACK DATA
			COURSE:292.	SPEED:10.4 KNOTS		ACC= 0.0 KTS/HR	
2506007	15.50N	105.20W			MAX WIND= 80.0 KTS		BEST TRACK DATA
			COURSE:294.	SPEED: 9.5 KNOTS		ACC= 0.0 KTS/HR	
2512007	15.90N	106.10W			MAX WIND= 80.0 KTS		BEST TRACK DATA

Table I. Sample BEST-TRACK Table.

natural coordinate system whose origin is at the computed position of the center of the vortex at the time of the report. This position is computed from BEST-TRACK data, and the transformation is accomplished in the following Manner: The BEST TRACK is searched to locate the proper six-hour segment, and the center of the vortex is located along that segment at a distance equal to the difference between the time of the last BEST-TRACK position and the time of the report multipled by the average speed of movement of the center along that segment. With the location of the origin thus fixed, the position of the report is converted into polar coordinates (r, θ) , where r is the radial distance in nautical miles from the center of the vortex to the position of the report and θ is the angle measured clockwise from true north to the radial line joining the center of the vortex and the position of the report. See Figure 1. The entire polar coordinate system is then rotated through the angle ϕ, the smaller angle between the direction of vortex movement and true north, so that the direction toward which the cyclone is moving coincides with true north. See Figure 2. At this point the position of the report relative to the center is then reconverted into a Cartesian Coordinate System in which the distance along both axes is measured in nautical miles. (This interim conversion to polar coordinates was made only to facilitate the rotation of the axes, since rotation is accomplished more easily in a polar coordinate system than in a Cartesian Coordinate System.) In terms of this new Cartesian Coordinate System, the direction toward which the cyclone is moving represents positive values of Y and directions to the right of the

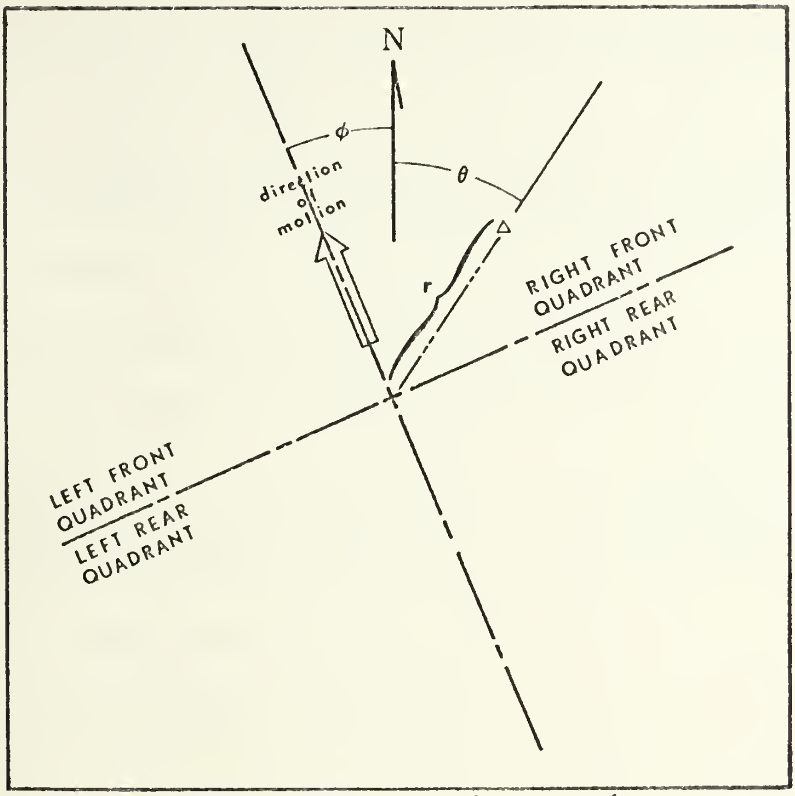

Figure 1. Polar and geographic coordinate systems

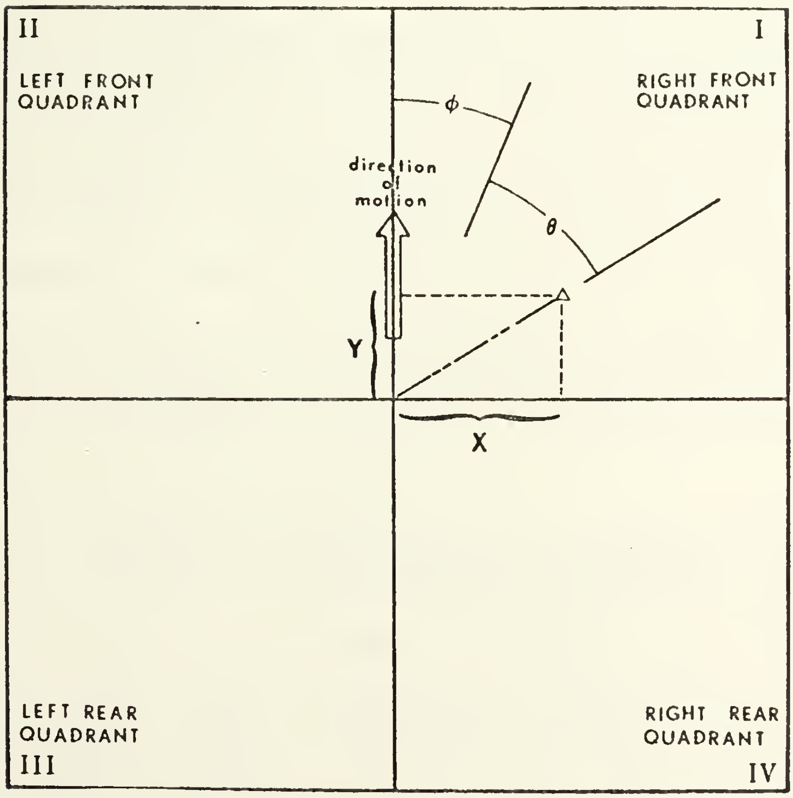

Figure 2. Cyclone-centered natural coordinate system

track represent positive values of X. In current cyclone nomenclature, the right-front, left-front, left-rear, and right-rear quadrants of the cyclone correspond, respectively, to the first (I), second (II), third (III), and fourth (IV) quadrants of the new Cartesian Coordinate System. Therefore, in Figure 3, the schematically represented report lays in the right-front/I quadrant. The net effect of this transformation is the creation of a moving natural coordinate system whose origin is at the center of the vortex, and whose speed and direction of movement is that of the cyclone itself.

The use of BEST-TRACK data in the transformation procedure is believed to be quite accurate, since in every case where a comparison could be made between a vortex center position computed from BEST-TRACK data and an actual aircraft fix of the center, the difference between the computed position and the reported position was less than the aircraft's estimated error in navigational position. (In the DETAILED EYE Report the location of the center is reported along with an estimate of the accuracy of the navigational fix, usually ranging from 2-50 miles.) For this reason, and to preserve continuity in the calculations, computed positions are used in the transformation of coordinates even though an actual fix might be available for the time of a report.

Once the decoding and transformation of coordinates is completed, the program then produces an output of one or more punched cards, according to the type of report. Each RECCO Report produces one card, each DETAILED EYE Report produces up to four cards, and each DROPSONDE Report produces up to seven cards. These cards contain the decoded data,

with all positions given in terms of the natural coordinate system, and are used as data for PROGRAM TWO. Additionally, a table is printed containing the decoded information (see Table II). In this table the positions are given in the geographic coordinate system as well as in the natural coordinate system.

B. PROGRAM TWO

PROGRAM TWO consists of a main program and three subroutines. It also performs three major functions: i) storing the data, ii) assembling the data, and iii) analyzing the data. It takes as input the decoded data cards produced by PROGRAM ONE and produces as output both printed tables and analyses drawn on the CALCOMP plotter.

The program reads the data and stores them in a series of vectors, with a separate vector for each type of information (e.g., one for wind speed, one for wind direction, etc.). At the option of the user, a table may be produced at this point containing an "echo check" of the data cards as they are read.

Next, a check is made to determine whether or not flight level analyses are desired and, if so, for which flight level. If no flight level plots are requested, the program checks to see whether D-value analyses are desired as described below. If flight level plots have been requested, a search is then begun through the vector containing the flight-level data. When a flight level is found which lays within plus or minus 500 meters of the requested level another check is made to determine whether or not

CYCLONE NAME : OLIVIA PAGE 3 OF

SEP 1971

OB	DAY/TIME	LATITUDE	LONGITUOE	FLIGHT LEVEL	WIND DIRECTION	SPEED	AIR TEMPERATURE	OEW POINT TEMPERATURE	STANOARO SURFACE	HEIGHT	TYPE REPORT
4	2617097	? 20.8 N	?110.4 W	7610.0M	087	35.0 KTS	-15.0 C	-22.0 C	400 MB	7580.0 M	RECCO
			Y= 107.7 NM X= 16.9 NM	(NATURAL COORDINATES)		MAX WINO=	99 KTS	19.2 N 109.5 W	(COMPUTEO EYE POSITION)		

****

EYE FIXED BY PENETRATION AT 261800Z

REPORTEO POSITION	19.3 N	109.6 W	AIRCRAFT REPORT	MIN SEA LEVEL PRESSURE	948 MB
COMPUTED POSITION	19.3 N	109.6 W	BEST TRACK DATA	EYE SHAPE	CIRCULAR
OIFFERENCE	Y= -1.9 NM	X= -1.1 NM	NATURAL COORDINATES	DIAMETER	17 NM
ESTIMATED ACCURACY	5 NM		AIRCRAFT REPORT		

****

OB	DAY/TIME	LATITUDE	LONGITUOE	FLIGHT LEVEL	WIND DIRECTION	SPEED	AIR TEMPERATURE	OEW POINT TEMPERATURE	STANOARO SURFACE	HEIGHT	TYPE REPORT
5	2618007	19.3 N	109.6 W	2609.0M	###	###	###	###	700 MB	2609.0 M	EYE
			Y= 0.0 NM X= 0.0 NM	(NATURAL COOROINATES)		MAX WINO=	100 KTS	19.3 N 109.6 W	(COMPUTEO EYE POSITION)		
5	2618007	19.5 N	111.3 W	2800.0M	146	90.0 KTS	11.0 C	###	700 MB	2800.0 M	EYE
			Y= 15.3 NM X= -97.8 NM	(NATURAL COORDINATES)		MAX WINO=	100 KTS	19.3 N 109.6 W	(COMPUTED EYE POSITION)		
5	2618007	19.6 N	109.6 W	SURFACE	###	100.0 KTS	###	###	###	###	EYE
			Y= 19.7 NM X= -3.5 NM	(NATURAL COORDINATES)		MAX WINC=	100 KTS	19.3 N 109.6 W	(COMPUTEO EYE POSITION)		
7	2618007	? 19.3 N	?109.6 W	SURFACE	###	###	24.0 C	20.9 C	###	###	OROPSONOE
			Y= 0.0 NM X= 0.0 NM	(NATURAL COORDINATES)		MAX WINC=	100 KTS	19.3 N 109.6 W	(COMPUTEO EYE POSITION)		
7	2618007	? 19.3 N	?109.6 W	###	###	###	###	###	1000 MB	###	OROPSONOE
			Y= 0.0 NM X= 0.0 NM	(NATURAL COORDINATES)		MAX WINO=	100 KTS	19.3 N 109.6 W	(COMPUTEO EYE POSITION)		
7	2618007	? 19.3 N	?109.6 W	942.0M	###	###	20.0 C	20.0 C	850 MB	942.0 M	OROPSONOE
			Y= 0.0 NM X= 0.0 NM	(NATURAL COORDINATES)		MAX WINC=	100 KTS	19.3 N 109.6 W	(COMPUTEO EYE POSITION)		

"?" SHOWS DATA TO BE OF QUESTIONABLE ACCURACY "###" INOICATES MISSING OATA

Table II. Sample table of decoded data.

the point lays within the specified distance of the center (see below). If the point is found to lay near enough to the center, (i.e. within the grid) further tests may be made, at the option of the user, for stage of development, year, month, etc. This optional test allows the data to be assembled in an almost limitless number of combinations, according to the type of research being conducted. Once all tests have been successfully completed, the wind speed, wind direction, dry-bulb and dew-point temperatures, and the positional information are extracted and set into new storage arrays.

The same tests are conducted for each point in the flight-level vector until all points which meet the specified criteria have been identified and shifted into the new storage array. At this point, the assembly of the data is complete. The data are stored separately and are ready to be passed to the subroutines for analysis.

The actual analysis is performed in two steps. In the first step the data points, whose positional information is given in terms of Cartesian Coordinates (X,Y), are passed to subroutine GRID, which is an integral part of PROGRAM TWO. This subroutine takes these randomly placed data points and interpolates them into a 21 x 21 grid which is centered over the center of the vortex. This grid is then passed to the library subroutine CONTUR which draws the actual analysis using the CALCOMP plotter.

A check is then made to determine whether or not D-value analyses are desired, and a similar process is followed in selecting these points and performing the analysis. In this case, the selection criterion specifies

that the report point lay exactly at the required pressure level rather than within some specified pressure range of that level.

During a single run of PROGRAM TWO, any combination of the following analyses may be generated at the option of the user:

a. At a specified flight level:

(1) isotach analysis (10 kt interval)

(2) isotherm analysis (5 C interval)

(3) isodrosotherm analysis (5 C interval)

b. At any two isobaric surfaces:

(1) D-value analysis (50 m interval)

Again, at the option of the user, a table may be generated showing the data points selected for use in each of the analyses.

The isotach, isotherm, and isodrosotherm analyses are performed in the vicinity of a particular altitude rather than at a specific pressure level, since current reporting procedures specify that wind speed and dry-bulb and dew-point temperatures be reported by the aircraft at flight level (in meters) rather than as values extrapolated to the nearest standard pressure surface.

IV. THE PROCEDURE

The year 1971 was arbitrarily chosen as a prototype year for the study. The Naval Weather Service Environmental Detachment, National Climatic Center, Asheville, North Carolina, provided copies of the worksheets submitted by United States Air Force aircraft on cyclone reconnaissance flights during that year. These sheets yielded 471 RECCO Reports, 28 DETAILED EYE Reports, and 59 DROPSONE Reports, for a total of 558 reconnaissance reports of all types. All available information leads this researcher to believe that this represents approximately 95% of all cyclone data recorded by EASTROPAC reconnaissance aircraft in 1971. The BEST-TRACK information was obtained from the Fleet Weather Central Guam Annual Typhoon Report 1971 [7], and the maximum sustained wind information was taken from the official forecast bulletins issued by Fleet Weather Central (now Fleet Weather Facility) Alameda, California.

PROGRAM ONE was then tested using a small portion of actual data from the year 1971. In order to minimize the time required to test the analysis scheme, a contrived data set was used to test PROGRAM TWO. The results of this test are shown in Figures 3 and 4. Figure 3 is a sample isotach analysis produced from 174 data points. A hand-drawn (dashed line) analysis has been superimposed on the computer-drawn (solid line) analysis for comparison. Figure 4 is a sample D-value analysis produced by PROGRAM TWO from 59 data points. For comparison, the D-values at each of the data points have been superimposed on the computer drawn

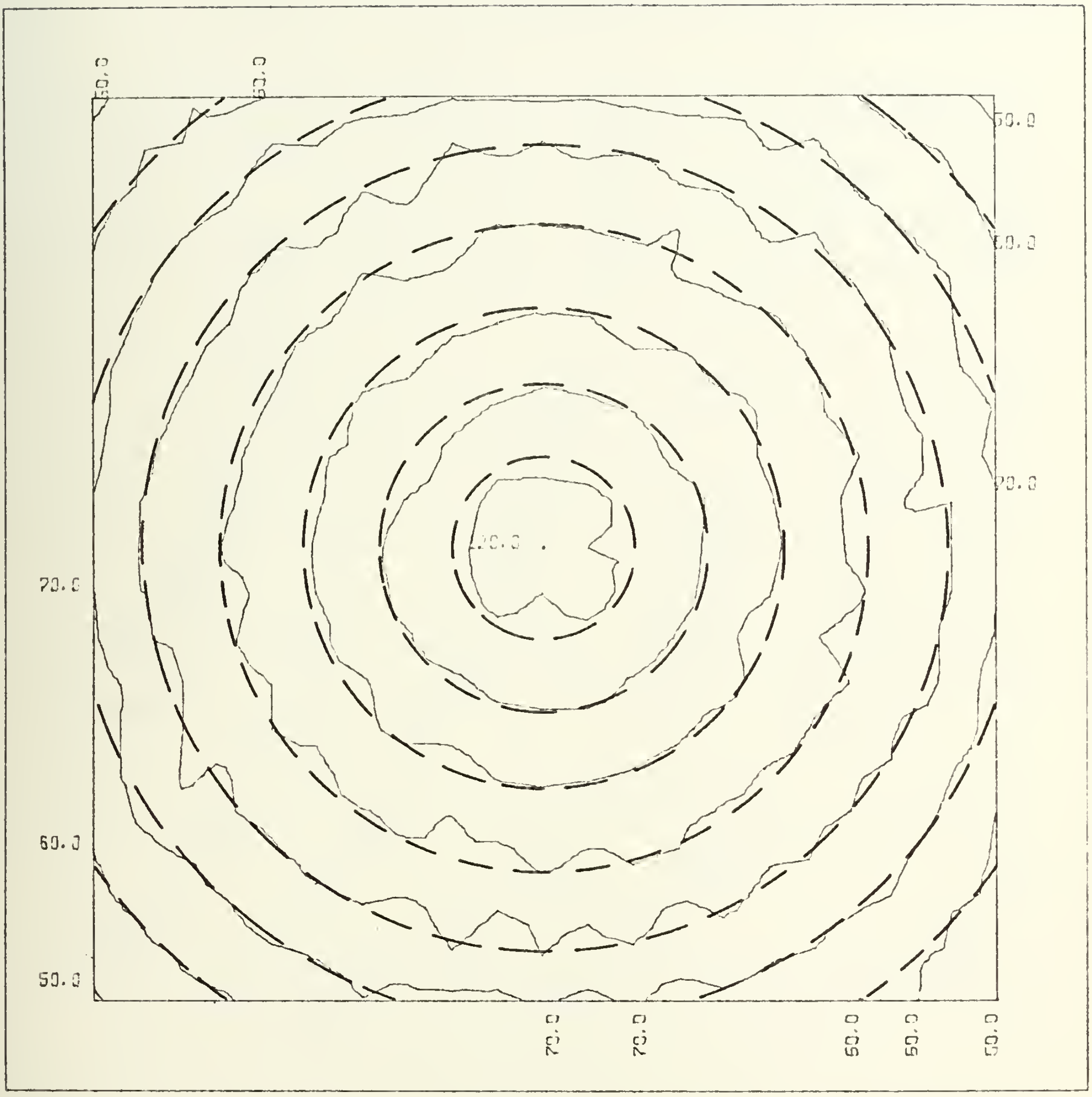

Figure 3. Sample isotach analysis drawn from 174 contrived data points.

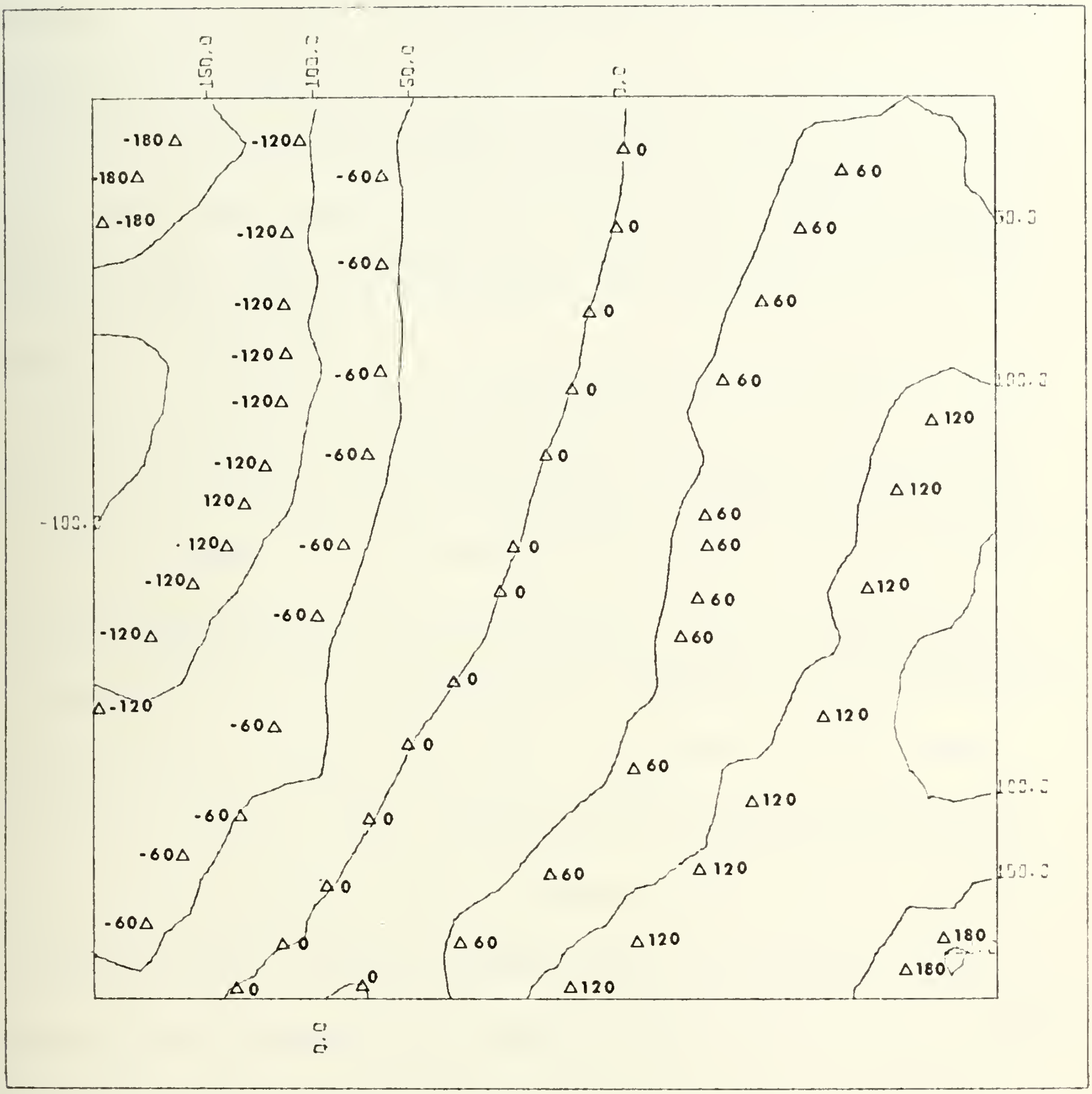

Figure 4. Sample D-value analysis drawn from 59 contrived data points.

analysis. These figures serve to illustrate the accuracy with which the analyses can be performed given a sufficiently dense data distribution.

Once the programs were tested and the parameters to be investigated had been chosen, the information contained on the worksheets had to be reduced to a form suitable for computer processing. A series of formats was devised, and each type of coded report (in raw form) was reduced to one or more punched cards for input to PROGRAM ONE. The data were manually verified from the printed tables, and a processed data set was punched by PROGRAM ONE.

With this data set as input for PROGRAM TWO, investigations were made into the structure of the 1971 cyclones during both tropical-storm and hurricane stages. (The tropical-depression stage was not investigated and is left as a topic for future research.) In each investigation a mesh length of 20 nautical miles was used in both the X and Y directions. Thus, the area over which the analyses were performed was a square, 400 nautical miles on a side, centered over the computed (BEST-TRACK) position of the composite cyclone. Selection of this area was based on the assumption that, for the parameters used, the contribution to the delineation of the structure of the cyclone by reports which lay at a distance of greater than 200 nautical miles from the center of the vortex would be negligible. Isotach, isotherm, and isodrosotherm analyses were made at flight levels of 3000 meters (near 700 mb), 5600 meters (near 500 mb), 7200 meters (near 400 mb), and 9200 meters (near 300 mb). D-value

analyses were made at the 1000-mb, 850-mb, 700-mb, 500-mb, 400-mb, 300-mb, and 200-mb pressure levels, using the United States Standard Atmosphere heights of each of the surfaces as the base value (i.e. D=O).

Before the gridding of the data points, the fields were initialized to the following values:

Isotachs	15 kt
Isotherms	0 C
Isodrosotherms	0 C
D-values	0 m

This initialization scheme applies very little bias to the data, allowing the computer to generate analyses which are largely determined by the actual data while conserving CPU time in the gridding.

The results of these investigations appear in the following section.

V. THE RESULTS

After processing by PROGRAM ONE, the 558 reconnaissance reports from the year 1971 yielded 898 data points to be used in the analyses. The following table contains a summary of the number of points which were found to be valid for each analysis within the previously stated selection criteria for each level investigated in the study.

Table III. Summary of 1971 Data

	Stage	
	Tropical Storm	Hurricane
3000 meters		
Isotach	23	21
Isotherm	43	38
Isodrosotherm	27	23*
5600 meters		
Isotach	4*	8
Isotherm	11*	14
Isodrosotherm	6	6
7200 meters		
Isotach	1	4
Isotherm	4	6
Isodrosotherm	3	3
9200 meters		
Isotach	5	4
Isotherm	8	5
Isodrosotherm	0	0
D-value Analyses		
1000 mb	20	1
850 mb	21	18*
700 mb	46	46
500 mb	14	16
400 mb	9	7
300 mb	20	11
200 mb	0	0

The analyses marked with an asterisk (*) appear as Figures 5-8.

Several prototype analyses are presented (Figures 5-8), more for evidence of a viable analysis routine than for diagnosis of tropical-cyclone structure. The following is a discussion of certain features of these analyses.

The isodrosotherm analysis in Figure 5 illustrates one type of problem which may be encountered in the use of a strictly objective analysis scheme over a sparse data area. The very dry cell analyzed in quadrant I, near the center of the figure, is believed to have been generated almost entirely by the -34 C report laying in the second quadrant approximately 20 nautical miles from the center. The value at this single point is more than 40 C lower than the value at any other point in the first or second quadrant except those which lay in close proximity to it. This fact, coupled with its position relative to the other points in these quadrants, caused the analysis scheme to generate the closed dry cell in order to obtain the proper gradient. The -32 C report (second quadrant, at approximately 15 nautical miles from the center) did not cause the same type of cell to be generated because of the absence of data in the third quadrant. However, it was responsible for the extension of the 5 C contour toward the lower left corner of the figure.

The isotach analysis in Figure 6 shows the type of analysis which can be generated from an extremely sparse data field. The most significant point in this analysis is the manner in which the 30 kt contour has been distorted in response to the 36 kt report.

The stair-like contour across the bottom of Figure 7 was caused by the lack of data in the area. The field was initialized to O C, and since most of the data lay in the vicinity of the center, none of the points lay close enough to this edge to be spread over the area during the scanning portion of the gridding process.

In Figure 8 the numerous closed centers were caused by the separation of data points, and the relatively large variation in values between these points. This 850-mb D-value analysis was drawn entirely from DROPSONDE data. In this case the position of the aircraft at the time that the drop was made has a great influence on the analysis, and is probably responsible for the fact that the lowest D-values are not symmetric about the cyclone center, as one might expect. This figure also exhibits a problem similar to that shown in Figure 5 as evidenced by the closed 200-m and 100-m centers located approximately 60 nautical miles from the center of the cyclone. In this case the problem was believed to have been caused by the relationship of the position of the densely packed negative area at the center of the figure to the position of the two positive 65-m reports (first and third quadrants). During the scanning portion of the gridding process the computer generated the positive centers to maintain a consistency in the gradient. Here again, the problem appears to lay in the sparsity of the data and should be aleviated once more points are added to the data set.

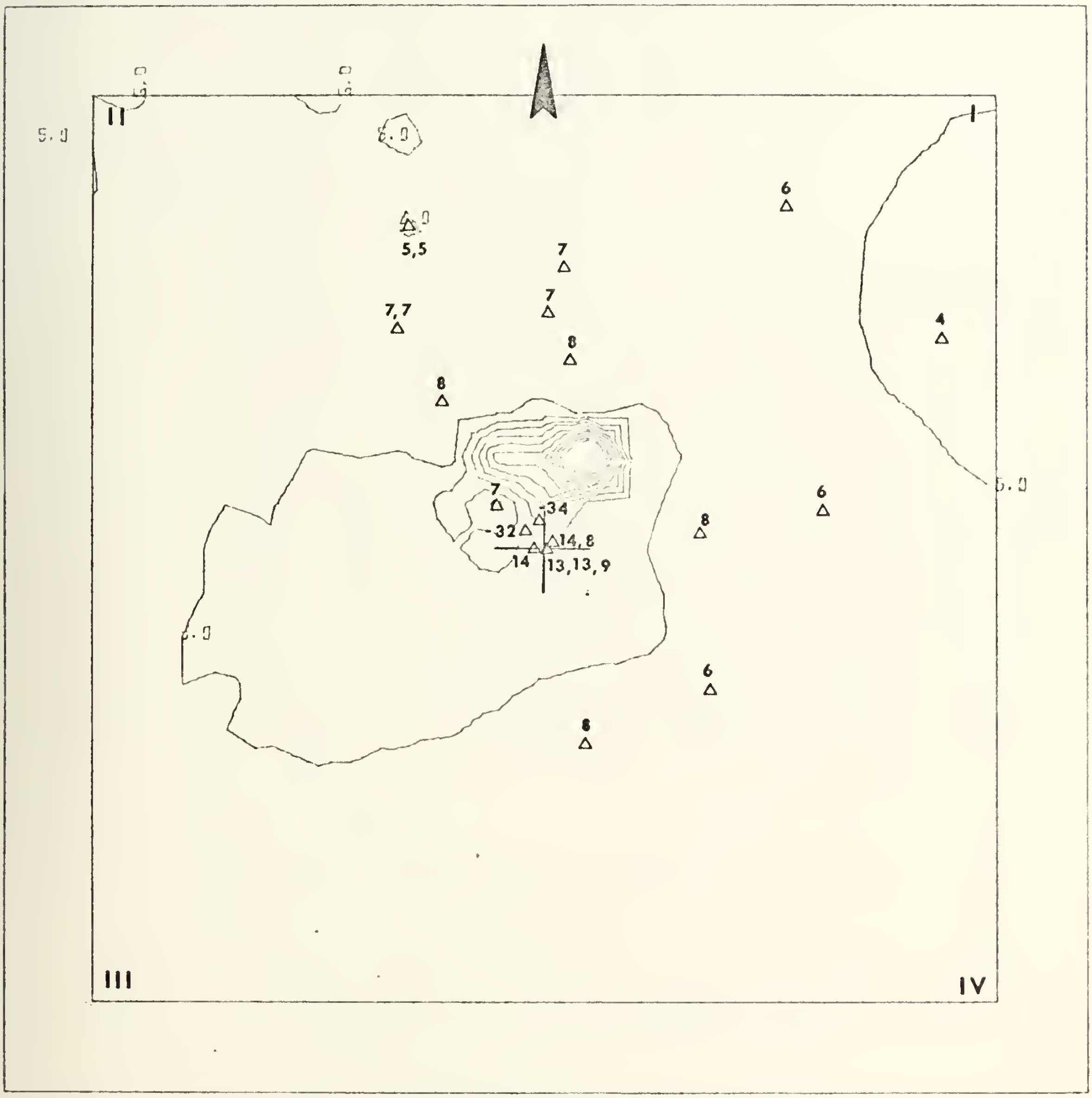

Figure 5. 3000-meter, hurricane-stage isodrosotherm analysis drawn from 23 data points using a 5-C contour interval. Scale: 1"=80 n mi (1971 data).

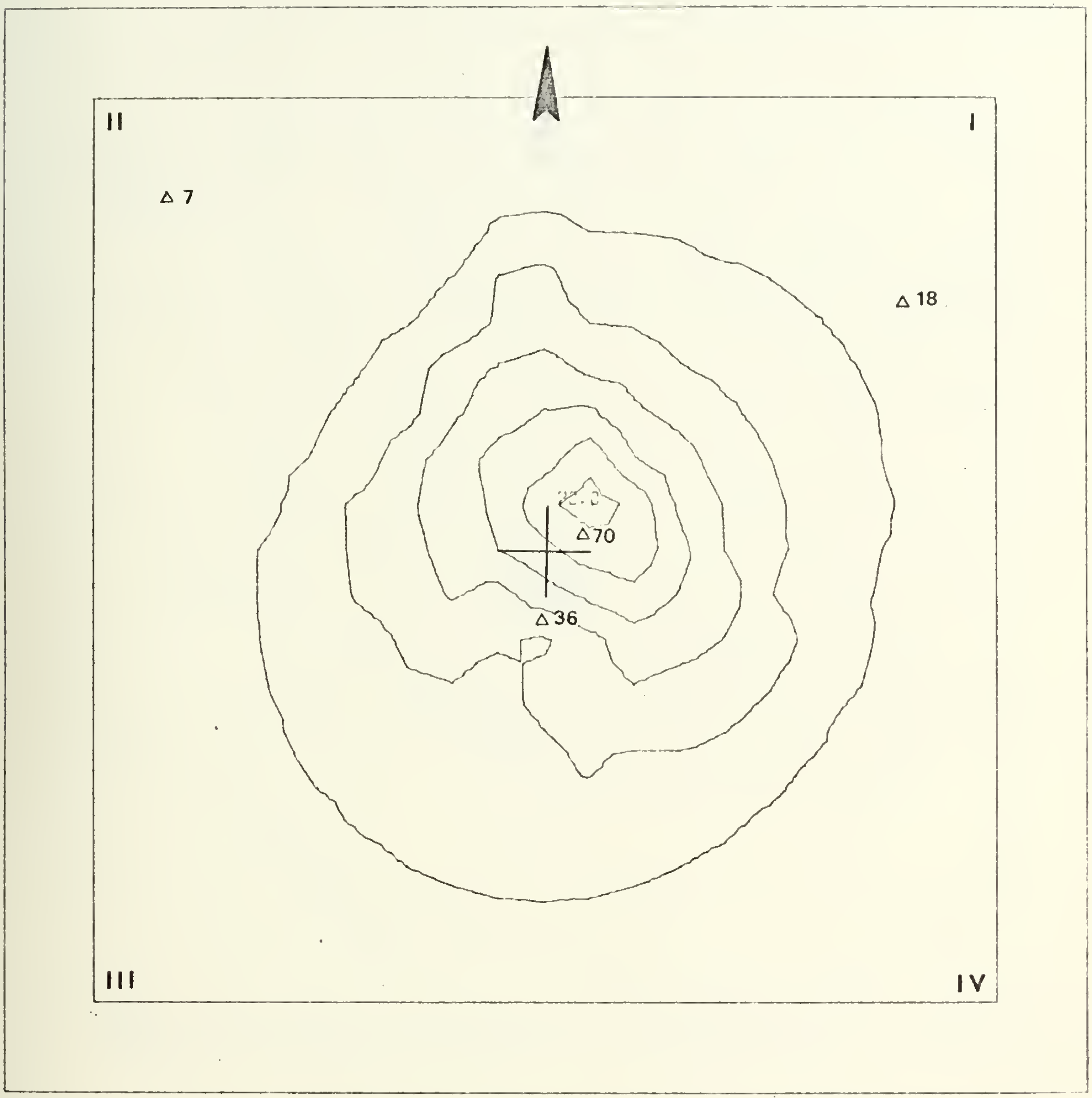

Figure 6. 5600-meter, tropical-storm stage isotach analysis drawn from 4 data points using a 10-kt contour interval. Scale: 1"=80 n mi (1971 data).

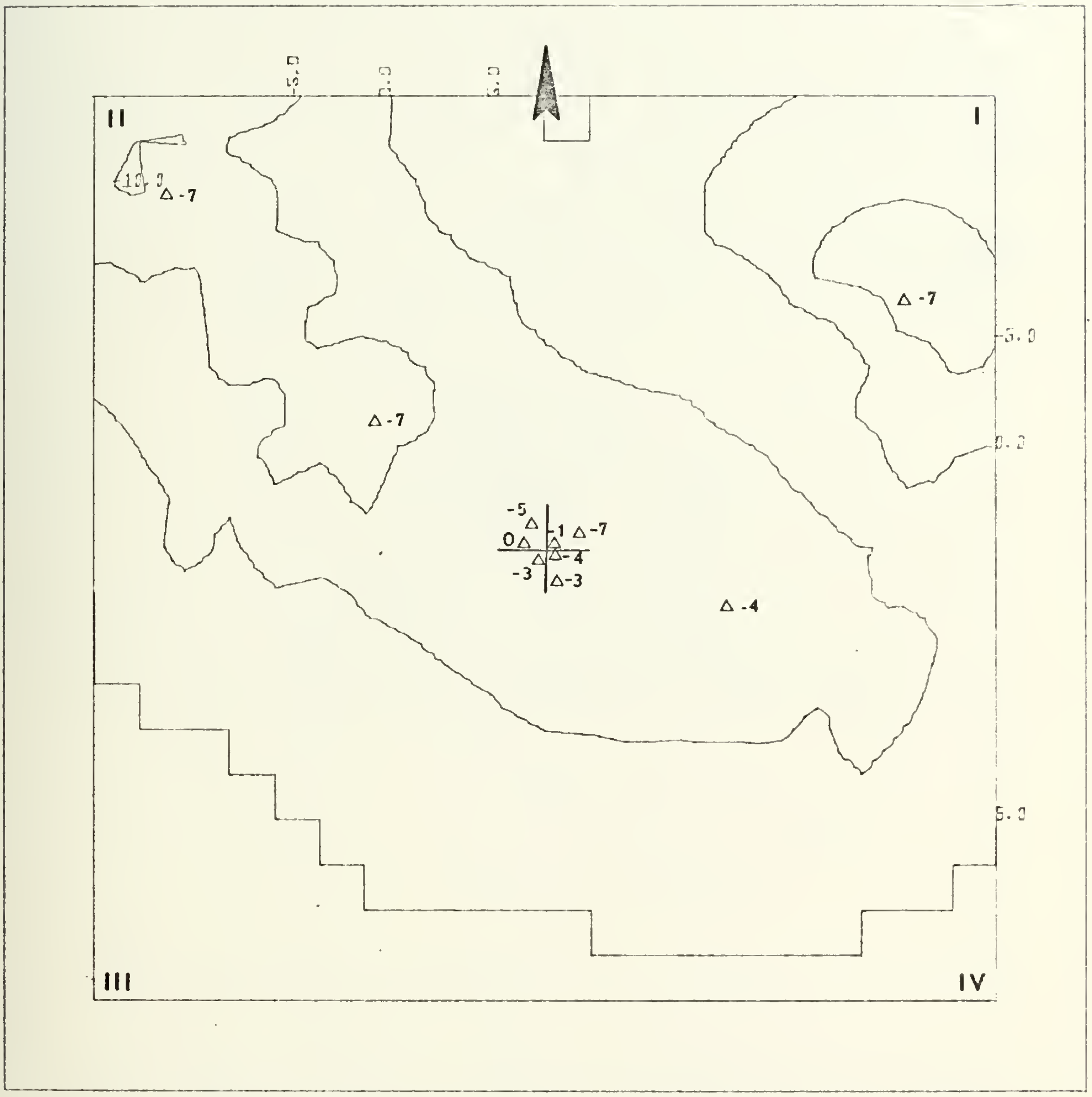

Figure 7. 5600-meter, tropical-storm stage isotherm analysis drawn from 11 data points using a 5-C contour interval. Scale: 1"=80 n mi (1971 data).

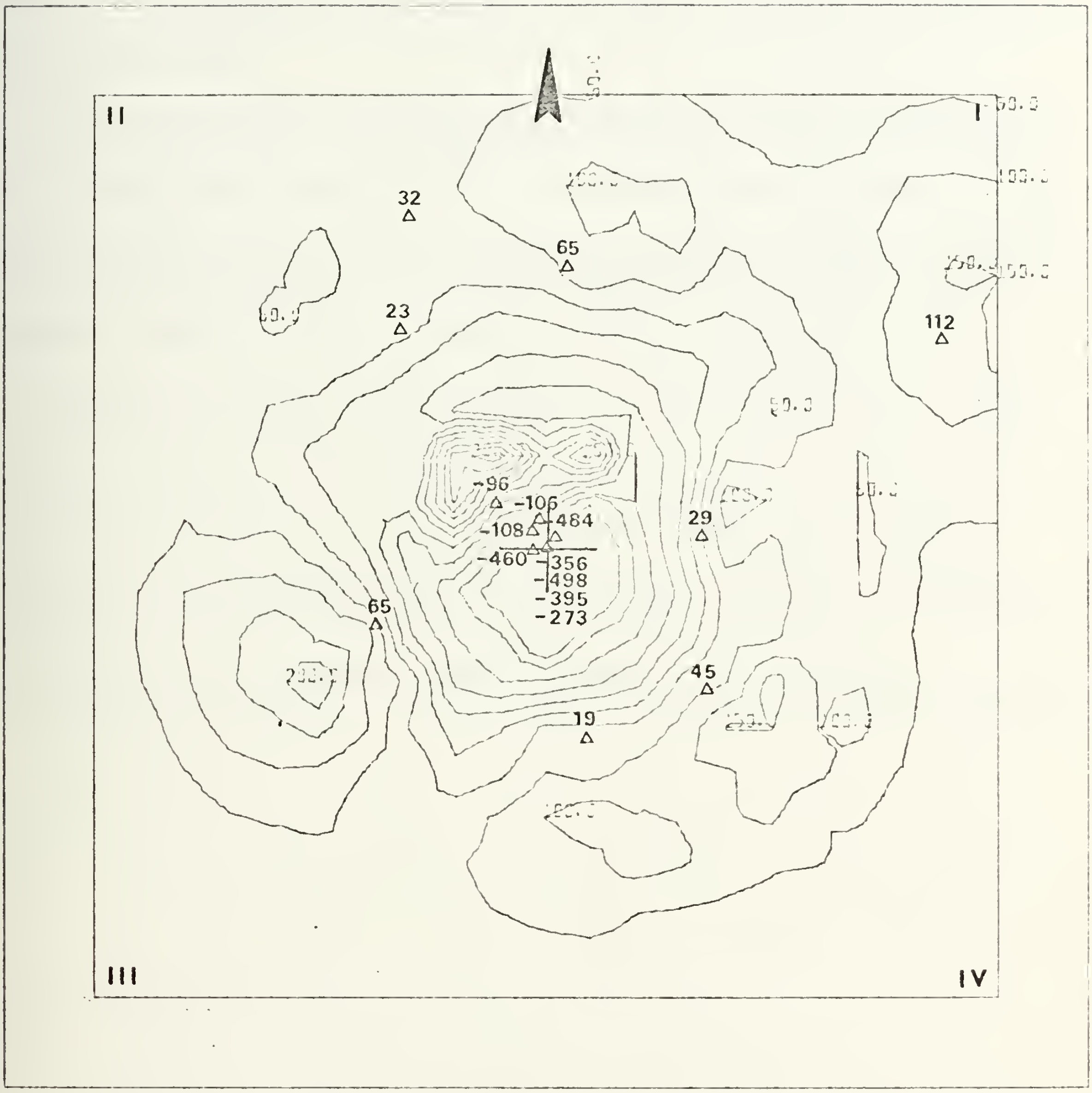

Figure 8. 850-mb, hurricane-stage D-value analysis drawn from 18 data points using a 50-m contour interval. Scale: 1"=80 n mi (1971 data).

VI. CONCLUSIONS

1. The computer routine developed for the processing and analyzing of aircraft reconnaissance data performs as designed and is now ready for more extensive use.

2. No meaningful determination of the structure of eastern tropical North Pacific (EASTROPAC) cyclones could be made from one year's data. Nevertheless, 1971 was adequate as a prototype year for the purpose of developing the computer routine for processing aircraft reconnaissance data.

3. The majority of the 1971 data collected by aircraft on cyclone reconnaissance missions in EASTROPAC were taken at points too far from the center of the vortex to be of use in a study concentrating on structural characteristics of the relatively small EASTROPAC cyclone, as evidenced by the small number of points found to be valid for the analyses.

VII. SUGGESTED TOPICS FOR FUTURE RESEARCH

1. Since the computer routine appears adequate for the processing and analysis of EASTROPAC reconnaissance data, the first objective of future research should be the compilation of a complete data set using all reconnaissance data gathered from 1964 to date. (Such is already in progress as a follow-up Master of Science Thesis in the Department of Meteorology, Naval Postgraduate School, Monterey, California.)

2. Once a complete data set is compiled, analyses at (or near) each of the standard pressure levels should be made for each of the major stages of cyclone development (depression, storm, and hurricane stages).

3. Satellite interpreted tropical-cyclone data and ship-reported data should be researched and used to increase the data base.

4. Further, in connection with (1) above, the natural coordinate system used in PROGRAM ONE might be extended into time coordinates as well, using as a base value the time at which the particular cyclone reached its maximum intensity. Each reconnaissance report could then be placed at a time t hours before or after maximum cyclone intensity. This would allow more precise determination of the structure at various stages of development.

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ABSTRACT

A computer routine composed of two programs was developed to process and analyze aircraft reconnaissance reports for the purpose of diagnosing the structure of the tropical cyclones of the eastern North Pacific Ocean (EASTROPAC). The reports processed by the routine are the Reconnaissance, Detailed Vortex/Center, and the Dropsonde Reports.

Data from the year 1971 were used as a prototype set for the development of the computer routine. The reconnaissance observations were decoded by the first program and analyses were drawn by the second program at various levels between 1000-mb and 200-mb during the storm and hurricane stages of the tropical cyclones. The data proved to be adequate for the purpose of proving the workability of the computer routine, but insufficient for anything but a preliminary analysis of EASTROPAC cyclone structure.

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The application of aircraft reconnaissance data to the analysis of the structure of tropical cyclones of the eastern North Pacific Ocean.